E7.4-10818.

CR140620

# A Study to Explore the Use of Orbital Remote Sensing to Determine Native Arid Plant Distribution

Do not film

by

W.G. McGinnies (Principal Investigator),

E.F. Haase, L.K. Lepley, J.S. Conn,

H.B. Musick, and K.E. Foster



THE LAST BIANNUAL AND FINAL REPORT OF WORK
PERFORMED UNDER N.A.S.A. CONTRACT NO. NAS5-21812

(E74-10818) A STUDY TO EXPLORE THE USE OF ORBITAL REMOTE SENSING TO DETERMINE NATIVE ARID PLANT DISTRIBUTION Biannual Progress Report and Final Report (Arizona Univ., Tucson.) 38 p HC $3.75 CSCL 08F G3/43 N75-10544 Unclas 00818

Office of Arid Lands Studies
College of Earth Sciences
University of Arizona
Tucson, Arizona 85719
August, 1974

E74-10818
CR-140620

# A STUDY TO EXPLORE THE USE OF ORBITAL REMOTE SENSING TO DETERMINE NATIVE ARID PLANT DISTRIBUTION

by

W.G. McGinnies (Principal Investigator),
L.K. Lepley, E.F. Haase, J.S. Conn, H.B. Musick, and K.E. Foster

Last biannual progress report and final report
describing work under NASA contract No. NAS5-21812.





OFFICE OF ARID LANDS STUDIES
COLLEGE OF EARTH SCIENCES
UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85719

August, 1974

TABLE OF CONTENTS

ABSTRACT

This is the third biannual progress and final report describing results of NASA Contract No. NAS5-21812, A Study to Explore the Use of Orbital Remote Sensing to Determine Native Arid Plant Distribution. Significant results of the research include:

1. The theory of a method for determining the reflectivities of natural areas from ERTS data, taking into account sun angle and atmospheric effects on the radiance seen by the satellite sensor. Ground level reflectivity values can be calculated from ERTS MSS radiance values by the use of ground truth reflectivity data from two different calibration areas, radiance data from ERTS MSS imagery for the same two calibration areas, and for the areas in which reflectivity is to be determined. The resulting conversion factor can be used to determine the reflectivities of areas in the vicinity of the calibration areas.

2. Ground truth spectral signature data for various types of scenes, including ground with and without annuals, and various shrubs, were collected. When these data are plotted as infrared (MSS Band 6 or 7) reflectivity vs. red (MSS Band 5) reflectivity, clusters of data from the various types of scenes are distinct. This method of expressing spectral signature data appears to be more useful for distinguishing types of scenes than a simple infrared to red reflectivity ratio.

3. Large areas of varnished desert pavement are visible and mappable on ERTS and high altitude aircraft imagery. A large-scale and a small-scale vegetation pattern were found to be correlated with the presence of the desert pavement. The large scale correlation was used in mapping the vegetation of the area. It was found that a distinctive soil type was associated with the presence of the varnished desert pavement. The high salinity and exchangeable sodium percentage of this soil type provide a basis for the explanation of both the large-scale and small-scale vegetation patterns.

4. A radiometer-videorecorder interface was constructed that allowed radiometric data to be recorded on the sound track portion of a videotape as the terrain was recorded on the video portion. A low-altitude radiometric record of selected Avra Valley study sites was made with the equipment mounted in a light airplane. This data was compared to ground truth radiometric readings of the radiometric components of each study site which were collected the day following the overflight. This comparison shows quantitatively that

for most areas of desert vegetation, soils are the most influential factor in determining the signature of a scene.

5. Additive and subtractive image processing techniques were applied in the darkroom to enhance the vegetational aspects of ERTS MSS Bands 5 (red) and 7 (infrared). The photographic process made use of enlarged portions of ERTS linear density transparencies which included the Avra Valley study areas. A map of the natural vegetation of the Avra Valley was made using the enhanced final photographic product, high-altitude imagery and ground truth data.

ACKNOWLEDGEMENTS

The research reported herein was made possible by a grant from the National Aeronautics and Space Administration (Contract No. NAS5-21813). The research and administrative direction for this project were provided by the Office of Arid Land Studies, College of Earth Sciences at the University of Arizona.

Special appreciation is given to the following for their assistance in this research program: D.F. Post of the University of Arizona, College of Agriculture; C.W. Lowe and D.M. Slaymaker of the University of Arizona, Department of Biological Sciences; R.M. Turner of the United States Geological Survey; P.N. Slater and E. Rosen of the University of Arizona Optical Sciences Center; and J.E. Gray of the University of Arizona Medical Center.

# INTRODUCTION

In the past, the natural geography of plants was determined through studies conducted on the ground. At various locations on the globe, the flora has been analyzed to determine its species and community compositions. From these data boundaries of species, genera and community distributions are inferred.

While the distribution maps that arise from ground collected data show general outlines of distributions, they are by no means precise, since an extraordinary amount of data would be required to make a ground based distribution map exact. In an effort to gain an increased degree of preciseness in plant distribution mapping without spending the corresponding increased effort and funds, remote sensing has been used as a tool in collecting the necessary data.

It follows that satellites such as ERTS or other spacecraft should be the "ultimate" data gatherers for distribution mapping since their great distance from the earth lends them readily to the study of large areas of the earth's surface.

Our project, then, was to explore the use of orbital remote sensing to determine native arid plant distribution. In July, 1971, research was initiated toward the following objectives:

1. To determine the distribution of native plant species and plant communities in selected areas of the Arizona Regional Test Site (ARETS).
2. To determine the phenological variations in plant species in the arid regions of the Arizona Regional Ecological Test Site.
3. To determine unique spectral signatures for selected plant species and related site conditions.
4. To determine the feasibility of using ground truth imagery as an aid to interpretation of orbital imagery.
5. To use knowledge gained from ARETS studies in the interpretation of worldwide orbital imagery.

Following descriptions of the study areas, the significant results of the study are presented in two sections. The first section summarizes the results of research performed before August 15, 1973. Complete details of experimental proceedings are not included since these can be obtained from previous progress reports and referenced publications. The second section describes the research completed after August 15, 1973. A list of reports and publications resulting from our research is included in Appendix A.

## THE STUDY AREAS AND SYNOPSIS OF FINDINGS

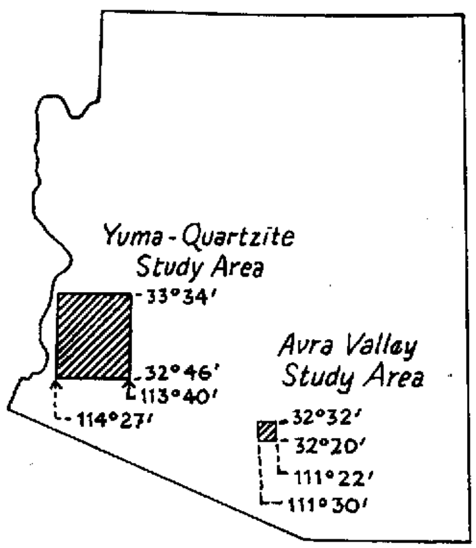
Two areas were extensively studied as a part of this project: The Yuma-Quartsite area and the Avra Valley area.

### Yuma-Quartsite Study Area

The Yuma-Quartsite area near Yuma, Arizona, represents extreme desert conditions with the lowest annual rainfall in Arizona. Typical vegetation communities of the area include: foothill paloverde (Cercidium microphyllum); ironwood (Olneya tesota); creosote bush (Larrea tridentata) ocotillo (Fouquieria splendens); and a combination of paloverde-ironwood and creosote bush-ocotillo. Pavement-like soils are characteristic of many areas of this region.

The vegetation, physiography, and soils of the Yuma-Quartsite area were studied during two trips made to the area. During the course of these studies it was found that large dark areas on the bajadas of the desert mountains correspond to areas of varnished desert pavement.

Large-scale and small-scale vegetation patterns were found to be correlated with the presence of the desert pavement. Using this correlation, a map was made of the area with the use of ERTS image #-1069-1744, high-altitude aircraft images, and ground truth data. As a part of the study, the nature of desert pavement soils was extensively studied. The map of the Yuma study area and the soils data are included in the Type II progress report for the period ending August 15, 1973.




STUDY AREAS

### Avra Valley Study Area

The Avra Valley study area, northwest of Tucson, is representative of the Sonoran Desert. This area received the most intensive investigation since it was in close proximity to Tucson and because of the floristic richness of the area.

Eight study sites were selected in the Avra Valley using high-altitude color and color infrared photography and ground truth information.

Homogeneous areas representative of the various vegetation types in the valley were chosen:

1,2,3 Larrea tridentata (creosote bush) and annuals: The sites are on different soil types and support different amounts or kinds of annuals and different densities of creosote bush;

4 Bouteloua rothrockii (Rothrock grama grass), Aplopappus tenuisectus (Burro weed), and annuals;

5 Prosopis juliflora (mesquite), Aplopappus tenuisectus, and Guitierrezia lucida (snakeweed);

6 Desert grassland; Aristida spp. and other perennial grasses, Prosopis juliflora, and Cercidium floridum (blue paloverde);

7,8 Cercidium mycrophyllum (foothill paloverde), Carnegiea gigantea (saguaro), Ambrosia deltoidea (triangleleaf bursage), and many other perennial species.

These sites were visited monthly so that information regarding the plant phenology of each area could be collected. At each site color infrared and regular color slides were taken simultaneously at various vertical, low-oblique, and high-oblique angles. The complete set of slides is the record of the plant phenology of each site for nearly one year.

Comparison of the relative abundances of vegetation at the sites to ERTS color-enhanced imagery of the same dates shows the importance of spring annuals in influencing the spectral signatures of the sites. The unusually high rainfall of 1972-73 resulted in a large abundance of spring desert annual plants. From the ground truth pictures it is known that these annuals grew in larger abundances on some sites than on others. This differential growth could be spotted on color enhanced ERTS imagery taken during the time of peak spring annual growth. It has been found that the differential growth of spring annuals in various communities may help to separate them on ERTS imagery.

In an effort to study the vegetational aspects of the ERTS imagery in a quantitative manner, radiometric data of the various radiometric components of areas as seen by the satellite scanner were collected and analyzed. Later, in May, 1974, radiometric surveys of selected portions of the Avra Valley area, including several of our study areas, were made from an aircraft flying at low altitude. Results of this line of research are reported in the section on new research.

## SIGNIFICANT FINDINGS PRECEDING AUGUST 15, 1973

### Spectral Signature Determinations from ERTS-1 MSS Data

A theory of a method for determining the reflectivities of the areas of interest from ERTS data has been developed. The method requires measurement of 1) the reflectivities of two different calibration areas, 2) the radiance of the two calibration areas on ERTS MSS imagery, and 3) the radiance of the area(s) on ERTS MSS imagery in which reflectivity is to be determined.

The model on which our theory is based describes the relationship between light incident on a scene, atmospheric effects, scene characteristics, and the resulting scene radiance as sensed by the multispectral sensor. The method allows for the conversion of ERTS MSS radiance measurements from a given overflight to ground level reflectivity values. The conversion factor can be used to determine the reflectivity of any area in the general vicinity of the calibration areas which has a similar overlying atmosphere. A complete mathematical description of this method is given in the Type II Progress Report of the period ending February 16, 1973.

### Ground Truth Spectral Reflectivity Signatures of Vegetation and Soil

To investigate the factors influencing the signatures of various areas, and to aid in classifying and separating these signatures, radiometric data for various types of scenes, including ground with and without annuals, and various shrubs, were collected at the Avra Valley study sites. Radiation in each MSS wavelength band was measured with an Exotech ERTS Radiometer. The reflectivity of each scene was then determined by dividing the reflected radiation measurement by the total incoming radiation measurement.

When these signature data are plotted as wavelength versus reflectivity or as the ratio of infrared to red reflectivity, comparison and classification of spectral signatures is difficult. However, when the signature data are plotted with infrared (MSS Band 6 or 7) reflectivity on one axis and red (MSS Band 5) reflectivity on the other axis, clusters of data from the various types of scenes are distinct.

The method of defining spectral signatures as a two-dimensional cluster where the two dimensions are reflectivity values in different wavelength bands could easily be extended to four dimensions (wavelength bands) with the aid of a computer. This method can characterize spectral signatures derived from ERTS data.

Analysis of Soils and Vegetation Associated with Desert Pavement of the Yuma Area

On ERTS imagery of Yuma County, there is a contrast between the dark tones of some bajadas and the lighter tones of other bajadas. Ground truth observations made at the Yuma study area in late March and early June 1973 revealed that the contrasts are due to the presence and absence of desert pavement. It was also revealed that there are vegetation differences between the bajadas with large areas of desert pavement and those bajadas lacking desert pavement. Using this ground truth correlation between the various types of desert pavement and vegetation present thereon, a vegetation map of the study area was prepared from ERTS image E-1069-1744. In addition to the ERTS imagery and ground truth data, imagery from NASA U-2 flight 73-016 was used in the preparation of the map. Six types of natural areas as well as agricultural areas were delineated and described. The map and descriptions are a part of the Type II progress report for the period ending August 15, 1973.

As a result of the analysis of soil samples collected at ground truth sites, it was found that a distinctive soil type was associated with the presence of the varnished desert pavement. In general, the desert pavement soils had a high exchangeable sodium percentage (ESP) and a low percentage of soluble salts. Desert pavement soils could be expected to be very impermeable to water due to the deflocculation of the clay colloids. It could be inferred that due to the impermeability of the desert pavement, which occurs on the interfluves, that the moisture relations of the rills and washes on the pavement bajadas present a more favorable habitat than do the rills and washes on the bajadas lacking desert pavement. Much more water would be expected to flow off of the desert pavement into the washes in desert pavement areas due to the relative impermeability to water of desert pavement soils. This postulated difference in moisture relations is the probable cause of the difference in vegetation between the bajadas with desert pavement and those without it.

The results of our investigations into the Yuma study area have been helpful to at least one investigator. In discussing our correlations between ERTS imagery and ground truth studies of the Yuma desert pavement areas with Carol Breed of the U.S. Geological Survey (MMC#331, A Study of Morphology, Provenance, and Movement of Desert Sand of Sand Seas in Africa, Asia, and Australia), we have aided in the interpretation of dark areas corresponding to the Yuma desert pavement areas which are seen on ERTS imagery of Saudi Arabia. This correlation was extremely important since ground truth data for many of Breed's, et al., study areas are scarce or non-existent, and for interpretation of ERTS imagery they must rely on comparisons with North American analogs for which ground truth data are available.

## RESEARCH AND SIGNIFICANT FINDINGS OF THE CURRENT HALF YEAR

### Edaphic and Topographic Factors in Relation to Annual Growth within the Avra Valley

A study was made in January 1974 to determine the possible causes for the differences in abundance of annual plants at the various Avra Valley study sites. Dr. D.F. Post, soil scientist of the Department of Soils, Water and Engineering, College of Agriculture, University of Arizona, participated in the study and collected the soils data.

At each site a pit was dug and the soil of each horizon was field analyzed as to texture, structure and carbonate content. The soil of each site was tentatively classified and fitted into the NCSS soils classification system that had been previously determined as a result of the Tucson-Avra Valley Area Soil Survey. After the soils had been classified into types and series, the additional known properties of the soils, available in the soil survey, could be inferred.

As is shown in Table 1, sites having soils with a comparatively high water-holding capacity in the upper few inches of the soil profile and with level topography had the largest abundance of spring annuals. This is of little surprise since the lack of water is the major limiting factor to plant growth in arid regions. Any factor that serves to increase the amount of water available for plant use in the upper inches of soil is of great benefit to plant establishment and growth.

It would be expected that soils with a high water-holding capacity would be of a greater benefit to annual plants than perennials in areas of ephemeral rainfall however. This is because annual plants can complete their life cycles in a short period of time, thus taking advantage of the abundant moisture held in the soil at relatively low tensions during the rainy season. Plants with longer life cycles would have to cope with the high moisture tensions associated with the high cation exchange capacity (CEC) of high water-holding capacity soils during dry periods.

### Photographic Image Enhancement Techniques and Discrimination of Plant Communities in the Avra Valley

Multispectral masking techniques developed by Molineux (1965), Stark, Barker, and Lee (1972a, 1972b), and modified by L.K. Lepley, were employed with ERTS Bands 5 and 7 to enhance the vegetational aspects of ERTS linear density transparencies which included the Avra Valley study sites.

As was shown by Stark, Barker and Lee (1972b) binary photographic masks can be combined in logical combinations so that only objects within a predetermined spectral signature range will be visible. Objects outside of this range are blacked out.

These spectral gates are referred to as "equivalence class masks" by Stark, et al., because they mask out everything except the class of objects possessing a specified brightness range within a certain spectral range.

Two logical sequences of equivalence mask combinations were devised to enhance native arid vegetation of the Avra Valley from ERTS data. Each sequence was carried out using June 25, 1973, ERTS MSS 9-inch transparencies (image #E 1337-17332). Bands 5 (.6-.7u) and 7 (.8-1.1u) were employed. Linear density transparencies were used because of their better definitions in light-toned areas where the native arid vegetation is often found. Figures 1 and 2 outline the steps in each sequence.

<u>Sequence Methods</u>

Both sequences began with the enlargement of ERTS MSS Bands 5 and 7 nine-inch linear density positive transparencies. The enlarged negatives were then contract printed onto ortho film. The exposure times were manipulated to correspond to the spectral thresholds characteristic of native arid vegetation. For Sequence I, the thresholds set for the production of the first high-contrast positives from the enlarged negatives was such that areas of known arid plant growth were nearly opaque for MSS Band 5 and nearly transparent for MSS Band 7 (see Figures 3 and 4). A high-contrast negative of Band 5 was made by contacting the high-contrast positive onto panchromatic film. Vegetation is nearly transparent on this transparency as is shown in Figure 5.

High-contrast positives were made from the enlarged Band 5 and 7 negatives to begin logic Sequence II. Threshold values for these transparencies rendered desert vegetation nearly transparent. Negatives of Bands 5 and 7 were made by contacting dense high-contrast positives that showed native vegetation to be nearly opaque. Vegetation was rendered nearly transparent on these negatives as is shown by Figures 6 and 7.

Sequence I

As is shown by the Figure 1 flow diagram, the first step of the logic combination (L.C.) is to double expose high-contrast positives of MSS Bands 5 and 7 on the same panchromatic sheet to produce an intermediate, $A_n$. As a result of the effects of the double exposure (image addition) vegetation is rendered middle grey, rock rendered transparent, and soil rendered dark as is shown in Figure 8.

Logic combination (L.C.) step 2 consists of sandwiching the high-contrast Band 7 positive and high-contrast Band 5 negative onto ortho film to produce intermediate B. This sandwiching, or image subtraction, results in the vegetation being rendered opaque while soil and rock are transparent (see Figure 9).

L.C. step 3 is to double expose intermediates A and B onto panchromatic film. On the resulting transparency vegetation is almost transparent, soil is grey, and rock is black as is shown by Figure 10.

Step 4 is to sandwich intermediates A and B onto panchromatic film. Vegetation is transparent, rock is black and soil is very light as a result of this sandwich as is shown by Figure 11.

Sequence II

The first step of the logic combination for Sequence II is to copy a sandwich of the high-contrast Band 5 negative and high-contrast Band 5 positive onto ortho film. As is shown by Figure 12, the resulting intermediate A shows vegetation to be nearly opaque while soils and rock are nearly transparent.

Step 2 is to copy a sandwich of a high-contrast Band 7 positive and a high-contrast Band 7 negative onto ortho film resulting in intermediate B. Vegetation is nearly opaque on this intermediate while soil and rock are nearly transparent (see Figure 13).

The third and final L.C. step for Sequence II is to copy a sandwich of intermediates A and B onto panchromatic film. In the final product vegetation is nearly transparent while soil and rock are nearly opaque (see Figure 14).

Table 2 outlines the component nature of the transparencies at each step and shows how they change as a result of image addition and subtraction.

## Analysis of Final Photographic Products

Both logic sequences enhance desert vegetation to a great degree. Sequence I products when viewed simultaneously through a multispectral viewer allow for the differentiation of 3 vegetation categories: saguaro-paloverde; riparian, and creosote bush. The Sequence II product allows for the differentiation of paloverde-saguaro, creosote bush, and riparian-silt and bare soil categories. The Sequence I equivalence class masking logic succeeds in separating the riparian communities from areas of bare soil while Sequence II logic does not. The Sequence II category boundaries are more distinct than are the Sequence I boundaries, however, since fewer resolution-lowering registering steps were required.

Boundaries of the before-mentioned vegetation and soil categories were traced on the view screen of a multispectral color additive viewer for Sequence I final products. These boundaries were checked against NASA high-altitude imagery and field observation. Actual riparian communities and areas of bare ground were found to correspond closely to the bare ground and riparian categories shown on the color enhanced Sequence I addition and subtraction transparencies.

In comparison to nonenhanced high-altitude color, color I.R., and SLAR imagery of the Avra Valley, the ERTS equivalence class products show the various categories of arid vegetation in a more distinct fashion. The paloverde-saguaro vegetation category is almost impossible to differentiate from the creosote bush category on high-altitude color and color I.R. imagery. Radar shows the distinction somewhat more clearly; but the distinction is most clear on the enhanced ERTS imagery. Areas of bare soil and riparian vegetation are much more detailed on high-altitude color, color I.R., and SLAR imagery however.

## Vegetation Map of Avra Valley Study Area

A vegetation map of a large portion of the study area was prepared from ERTS equivalence mask final products. In addition to the enhanced ERTS imagery and ground truth data, color imagery from NASA high-altitude mission No. 101, site 30, was used in preparation of the map. Agricultural areas and roads were delineated through the use of the high-altitude imagery but all other categories were taken from the ERTS images.

Descriptions of the Vegetation Types Mapped in Figure 15.

A. SILT AND BARE SOIL

Vegetation:

These areas are very sparsely vegetated, with only a few mesquite, *Prosopis juliflora*, and creosote bush, *Larrea tridentata*, growing. Many dead mesquite stumps are present, however, suggesting that these areas were vegetated in the not too distant past. A known drop in the water table due to the pumping of water for irrigation purposes may be the cause of the death of the mesquite.

Physiographic Relations:

Loose, silty soil occurs on level to slightly sloping topography. These barren areas are often on the outskirts of mesquite areas and are from 20 to 400 yards wide. It appears that these areas are very heavily sheet eroded.

B. RIPARIAN VEGETATION

Vegetation:

Very dense mesquite with a few large ironwood, *Olneya tesota*, form the canopy. Whitethorn acacia, *Acacia constricta*, occupies the middle strata and sometimes becomes arborescent. The herb-small shrub layer is largely absent under the dense canopy; however, snakeweed (*Gutierrezia lucida*), burroweed (*Aplopappus tenuisectus*) and wolf berry (*Lycium spp*), grow in the clearings where there is less shade.

Physiographic Relations:

The silty soil is heavily dissected and eroded. The water channels are deeply cut and are hard bottomed. The areas surrounding the mesquite areas are often severely sheet-eroded and devoid of vegetation.

C. CREOSOTE BUSH

Vegetation:

The creosote bush communities are comprised almost completely of creosote bush with a few small mesquite and triangleleaf bursage, *Ambrosia deltoidea*, intermixed. The washes are vegetated with large mesquite, blue paloverde, *Cercidium floridum*, and ironwood. Canyon ragweed, *Ambrosia ambrosioides*, and burroweed grow along the water course banks.

This vegetation category has less vegetation than any category except silt and bare soil.

Physiographic Relations:

The soil is generally silty and only slightly dissected. The topography is level and water channels are few and far apart. The individual creosote bushes are often surrounded by a mound of silt.

D. SAGUARO-PALOVERDE

Vegetation:

The vegetation of this category varies depending on its location on the mountains and bajadas. The category includes the creosote bush-paloverde-saguaro ecotone and is held together primarily by the copious presence of foothill paloverde (Cercidium microphyllum) and saguaro (Carnegia gigantea). As a whole, the saguaro-paloverde category has a much higher density than does the creosote bush or silt-bare soil categories.

On the lower bajadas creosote bush, mesquite, triangleleaf bursage, ironwood, ocotillo (Fouquieria splendens), burroweed, and several species of cholla (Opuntia) are found along with paloverde and saguaro.

In the washes large foothill paloverde, ironwood, canyon ragweed, mesquite and desert hackberry (Celtis pallida) are found.

Upper bajadas have much the same species composition, but with a few differences: ironwood and burroweed are not present; however, plants such as the barrel cactus (Ferocactus wislizeni), fairy duster (Calliandra eriophylla), limber bush (Jatropha cardiophylla), catclaw (Acacia greggii), ratany (Krameria parvifolia), teddy bear cactus (Opuntia bigelovii), desert zinnia (Zinnia pumila), and brittle bush (Encelia farinosa) are common.

At the higher elevations of the foothills and slopes of the Tucson Mountains, jojoba (Simmondsia chinensis) grows abundantly.

Physiographic Relations:

The mapped paloverde-saguaro community is found on the bajadas, foothills, and slopes of the Tucson Mountains.

Bajadas tend to be slightly to highly sloping. Soil particles vary from very fine (at the bottoms of the bajadas) to course (at the tops of the bajadas). Upper bajadas seem to be much more rocky than lower bajadas.

In general the bajadas are dissected by watercourses. The watercourses vary from a few meters across to more than 20 meters. The bottoms of the streambeds are usually sandy.

The foothills and slopes of the mountains are very rocky and quite steep. Rock outcroppings and cliffs are quite common.

Streambeds in the foothills and mountains are very steep and deeply entrenched. The bottoms of the stream channels are often solid rock.

## E. AGRICULTURAL LANDS

These areas were delineated to avoid confusion in interpreting the map; except for their rectangular pattern, fallow fields would be mistaken as silt-bare soil areas and planted fields would be mistaken for riparian areas on the enhanced ERTS transparencies.

## F. MOUNTAINS

The Tucson Mountains appeared as a distinct category even though the vegetation is of the saguaro-paloverde variety. The unique "dark" spectral appearance of the mountains is due to the abundance of rock and not to a vegetation difference.

BIBLIOGRAPHY

Molineux, C.E., 1965. Aerial Reconnaissance of Surface Features with the Multiband Spectral System. Paper presented at Third Symposium on the Remote Sensing of Environment, University of Michigan.

Stark, H., R.C. Barker and D. Lee, 1972. Some New Techniques for Processing Remotely Obtained Images by Self-Generated Spectral Masks. Applied Optics, Vol. I, II.

Stark, H., E. Garcia and R.C. Barker, 1972. Variance Measurements by a Coherent Optical Method with Applications to Image Processing. Applied Optics, Vol. II, IV.

An Airborne Radiometric Study of Portions of the Avra Valley

In an effort to compare the radiometric data collected at our Avra Valley sites to that collected by ERTS, an airborne radiometer-videotape recorder interface was designed to provide for the collection of radiometric data over selected Avra Valley study sites from a small aircraft. In our previous radiometric study of the Avra Valley sites, radiometric data were taken for the various components of each scene. It was then shown quantitatively that each radiometric component such as vegetation, soil, and litter of dead plants, differed from the other components radiometrically, but combined in some way to produce the overall radiometric signature. It was hoped that the low-altitude radiometric data when compared to ground-based radiometric data of the various scene components would yield information on how the components integrated to form the signature of a scene.

The System

The radiometric data collection system employed for the low altitude study made use of an Exotech ERTS radiometer that fed continuous data to a SONY AV-3400 video tape recorder via an interface. The system was developed by L.K. Lepley and based on a similar system used by A.M. Williamson of the Environmental Characterization Branch, Army Corps of Engineers. Construction and design was a result of the efforts of Evan Rosen, a member of the investigation team.

The terrain below the aircraft is viewed by a video camera that looks down the spotting scope of an Exotech ERTS radiometer as the image is recorded on magnetic tape. Simultaneously the data from the four channels of the radiometer plus spoken comments are coded by frequency modulation and entered on the sound track of the videotape.

The data collected represent a continuous record of the radiometric signatures of areas over which the airplane was flown. A SONY RF unit and a television set were employed with the videotape recorder to locate the portions of the tape on which the radiometric data of various study sites were recorded. A volt meter coupled to the interface was used to decode the data from the sites.

Airborne radiometric data were collected April 18, 1974, for six sites in the Avra Valley:

1) Rothrock grama grass site: supporting Bouteloua rothrockii (Rothrock grama) and Aplopappus tenuisectus (Burro weed and annuals);

2) Saguaro-Paloverde-Granite Rock site: Cercidium microphyllum (foothill paloverde), Carnegia gigantea (saguaro), Ambrosia deltoidea (triangle-leaf bursage), and many other perennial species;

3) Saguaro-Paloverde-Red Rock site: similar to site 2 but with many red rocks.

4) Larrea West Milewide Rd. site: Larrea tridentata (creosote bush) and annuals;

5) Green Field site: very heavy growth of corn;

6) Plowed Field site: bare plowed soil.

Ground truth data of the six sites were collected the day after the overflight.

Due to the malfunction of the interface, a back-up system was employed to record the data. This unit consisted of two volt meters coupled to the radiometer and a 35 mm single-lens reflex camera which recorded the meter readings as the aircraft passed over the study sites.

This system was flown May 21, 1974, over the six previously described Avra Valley sites. Ground truth data of the sites were collected the following day.

Airborne radiometric data plus ground truth radiometric data for the scene components were plotted as red (Band 5) versus infrared (Band 7) for each site except Bare Field and Green Field. The latter two sites were plotted together to facilitate comparison.

As is shown by the graphs (Figures 16-20), soils are the most important factor in determining the overall spectral signature of desert plant communities. Vegetation in these areas had only a small effect on the spectral signature. These results point out the difficulty in isolating and examining the relatively small vegetation parameter of the desert communities. In the face of such a large soil to vegetation ratio, large differences in green plant biomass are required to cause small differences in spectral signatures. Therefore, native arid plant communities with similar vegetation densities are difficult to separate.

## CONCLUSIONS

It is possible to determine, from ERTS imagery, native arid plant distribution. Using techniques of multispectral masking and extensive fieldwork, three native vegetation communities were defined and mapped in the Avra Valley study area. A map was made of the Yuma study area with the aid of ground truth correlations between areas of desert pavement visible on ERTS images and unique vegetation types.

With the exception of the Yuma soil-vegetation correlation phenomena, only very gross differentiations of desert vegetation communities can be made from ERTS data. Vegetation communities with obvious vegetation density differences such as saguaro-paloverde, creosote bush, and riparian vegetation can be separated on the Avra Valley imagery while more similar communities such as creosote bush and saltbush (occurring north of mapped area) could not be differentiated. This report suggests that large differences in vegetation density are needed before the signatures of two different vegetation types can be differentiated on ERTS imagery. This is due to the relatively insignificant contribution of vegetation to the total radiometric signature of a given desert scene.

Where more detailed information concerning the vegetation of arid regions is required, larger scale imagery is appropriate.

Table 1: Spring Annual Plant Abundance in Relation to Edaphic and Topographic Factors

| Site | Soil texture | | Topography | Spring annual plant abundance |
|---|---|---|---|---|
| Rothrock grama | surface-<br>subsurface- | loamy fine sand<br>sandy loam | level | many |
| Larrea-<br>North Sandario | surface-<br>subsurface- | sandy loam<br>sandy loam-light sandy clay loam | nearly level | many |
| Paloverde-Saguaro (white rocks) | surface-<br>subsurface- | loamy fine sand and gravel<br>sandy loam-light sandy clay loam | slightly sloping | few |
| Paloverde-Saguaro (red rocks) | surface-<br>subsurface- | gravelly loamy fine sand and rocks<br>gravelly sandy loam | 2-4% slope | few |
| Larrea-west Milewide | surface-<br>subsurface- | fine sandy loam-very fine sandy loam<br>fine sandy loam-very fine sandy loam | level | most |

Table 2: Scene Component Natures as Influenced by Multispectral Masking

LOGIC SEQUENCE 1

Logic Combination

Step 1 (double expose)

| | Band 5 (pos) | Band 7 (pos) | Result (neg) |
|---|---|---|---|
| vegetation | opaque | trans | gray |
| soil | trans | trans | dark |
| rock | black | black | trans |

Step 2 (sandwich)

| | Band 5 (neg) | Band 7 (pos) | Result |
|---|---|---|---|
| vegetation | trans | trans | black |
| soil | black | trans | trans |
| rock | white | black | trans |

Step 3 (double expose)

| | A | B | Result |
|---|---|---|---|
| vegetation | gray | black | light |
| soil | dark | trans | gray |
| rock | trans | trans | black |

Step 4 (sandwich)

| | A | B | Result |
|---|---|---|---|
| vegetation | gray | black | trans |
| soil | dark | trans | very light |
| rock | trans | trans | black |

Step 5 (double expose)

| | A | B | Result |
|---|---|---|---|
| vegetation | light | trans | black |
| soil | gray | very light | dark |
| rock | black | black | trans |

Table 2 (Cont'd)

LOGIC SEQUENCE 2

Logic Combination Step 1 (sandwich)

| | Band 5 (pos) | Band 5 (neg) | Result A |
|---|---|---|---|
| vegetation | nearly trans | nearly trans | nearly opaque |
| soil | trans | nearly opaque | nearly trans |
| rock | nearly opaque | trans | nearly trans |

Step 2 (sandwich)

| | Band 7 (pos) | Band 7 (neg) | Result B |
|---|---|---|---|
| vegetation | nearly trans | nearly trans | nearly opaque |
| soil | trans | opaque | trans |
| rock | opaque | trans | trans |

Step 3 (sandwich)

| | A | B | Result |
|---|---|---|---|
| vegetation | nearly opaque | nearly opaque | nearly trans |
| soil | nearly trans | trans | nearly opaque |
| rock | nearly trans | trans | nearly opaque |

FIGURE 1: FLOW DIAGRAM SEQUENCE I

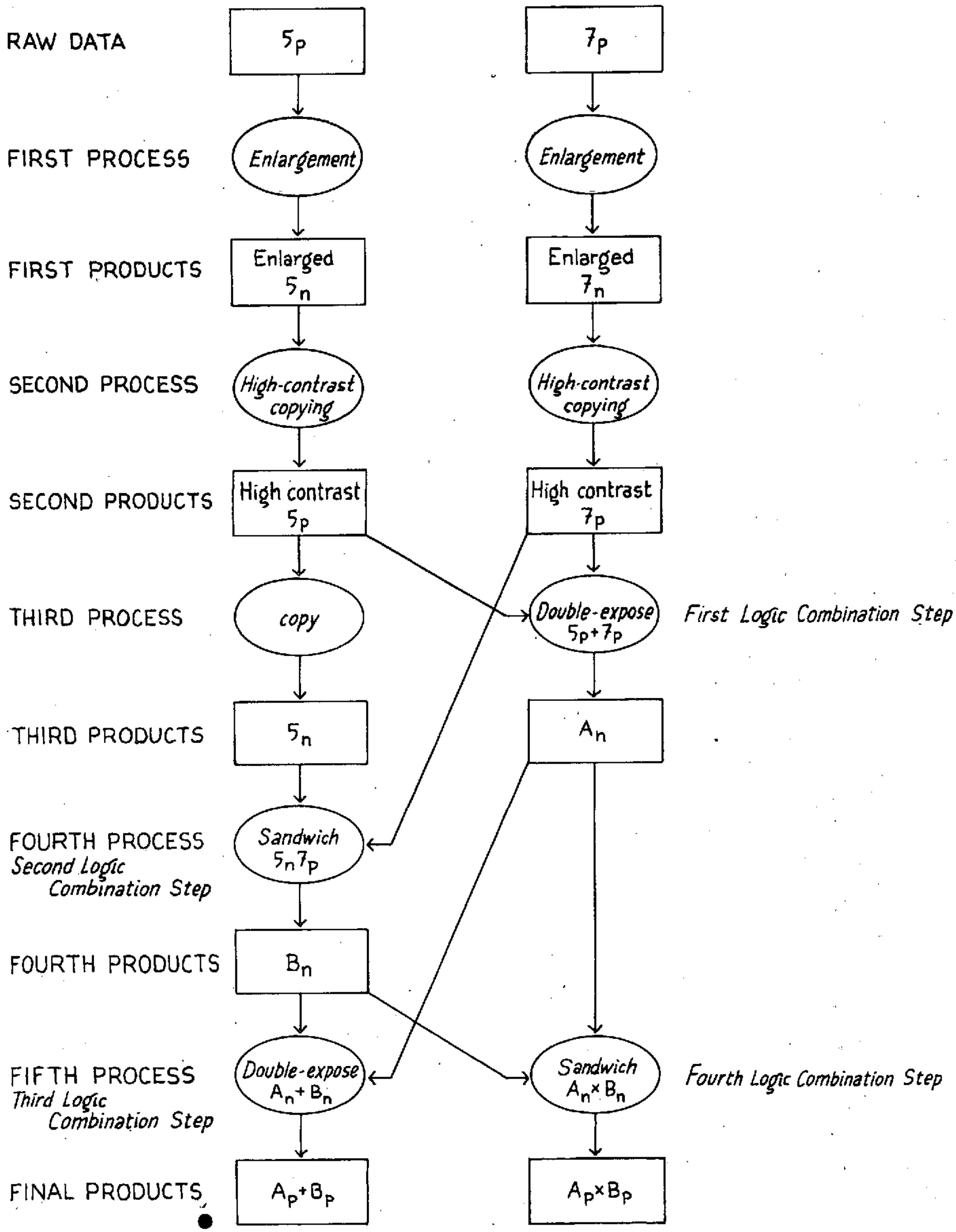


FIGURE 2: FLOW DIAGRAM SEQUENCE II

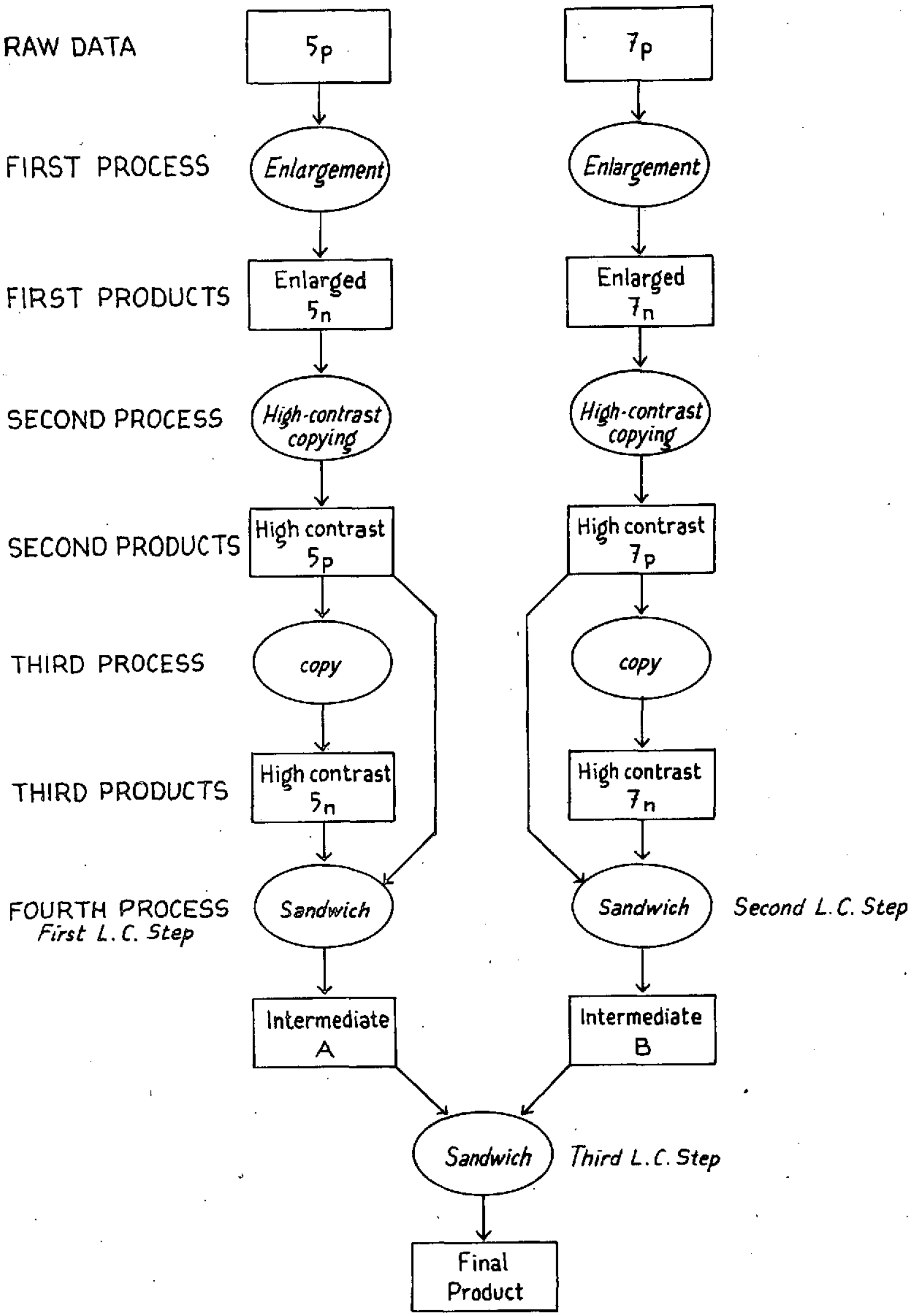


Figure 3: High-contrast Band 5

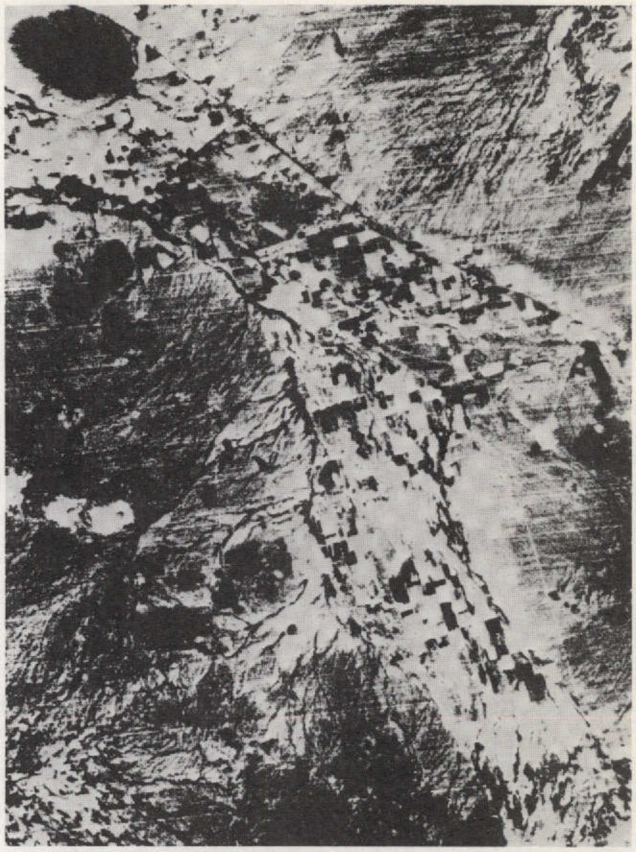


Figure 4: High-contrast Band 7

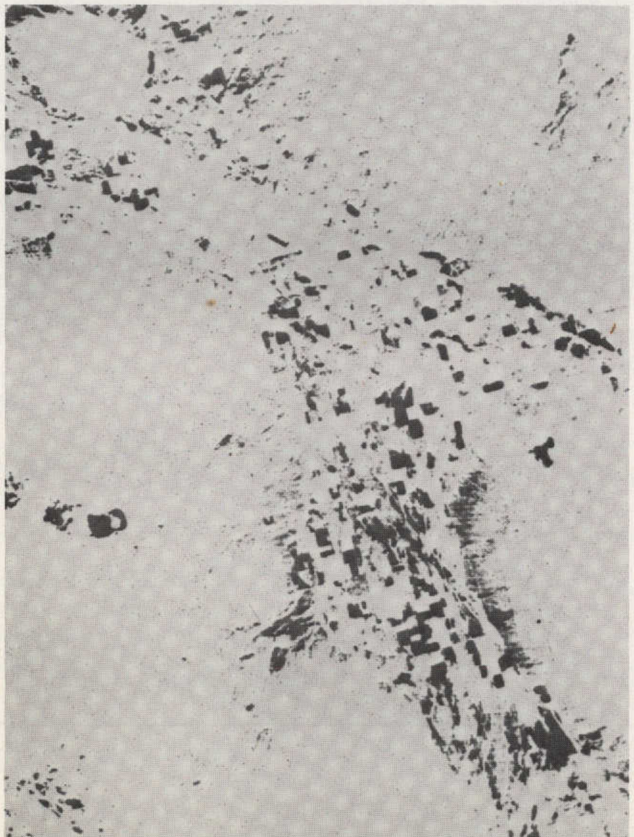


Figure 5: Negative, Band 5

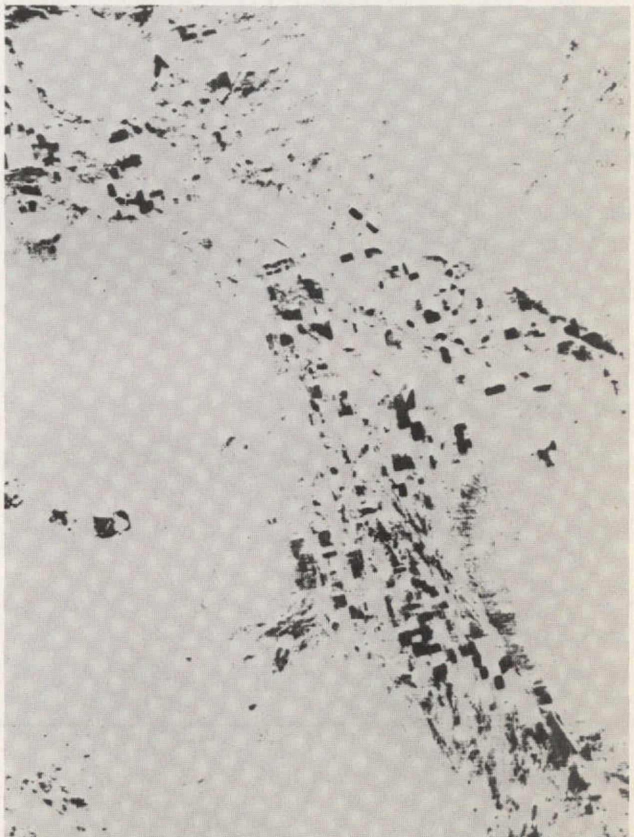


Figure 6: Negative, Band 7

Figure 7: Negative, Band 5

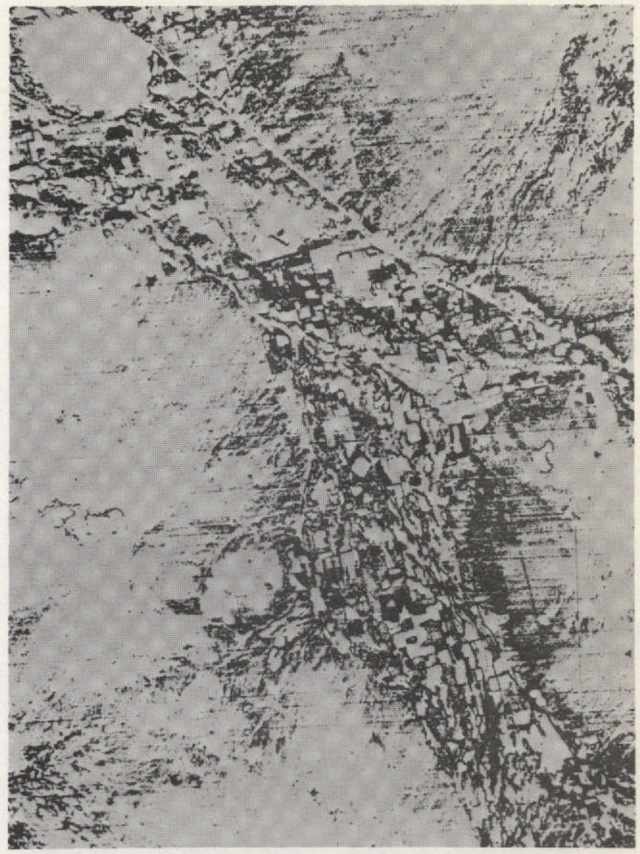


Figure 8: Method I, Intermediate A

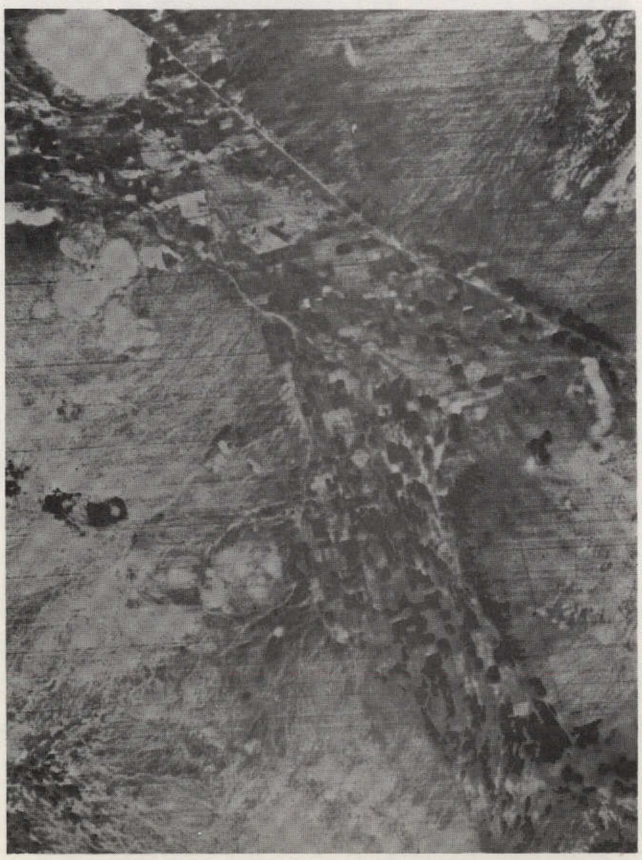


Figure 9: Method I, Intermediate B

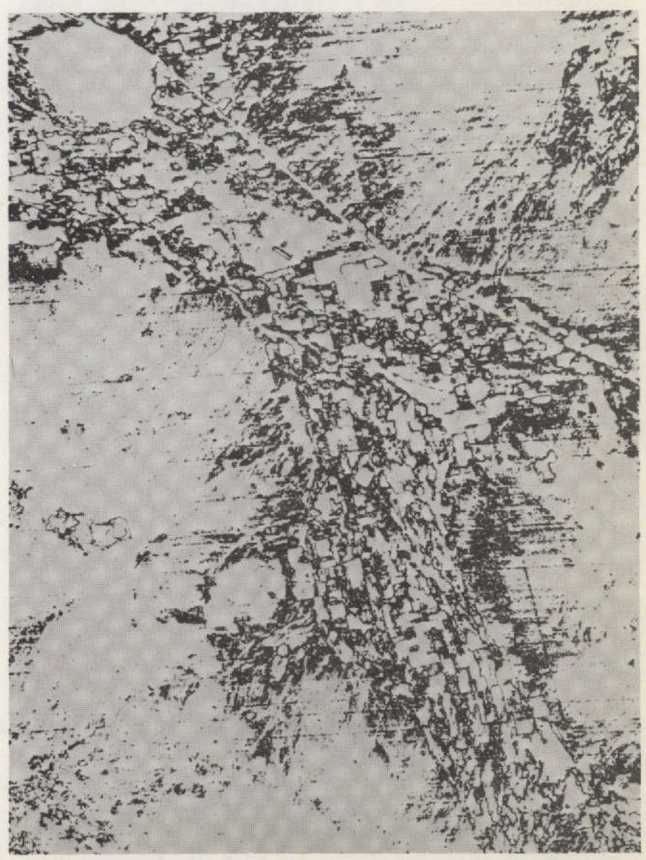


Figure 12: Method II, Intermediate A

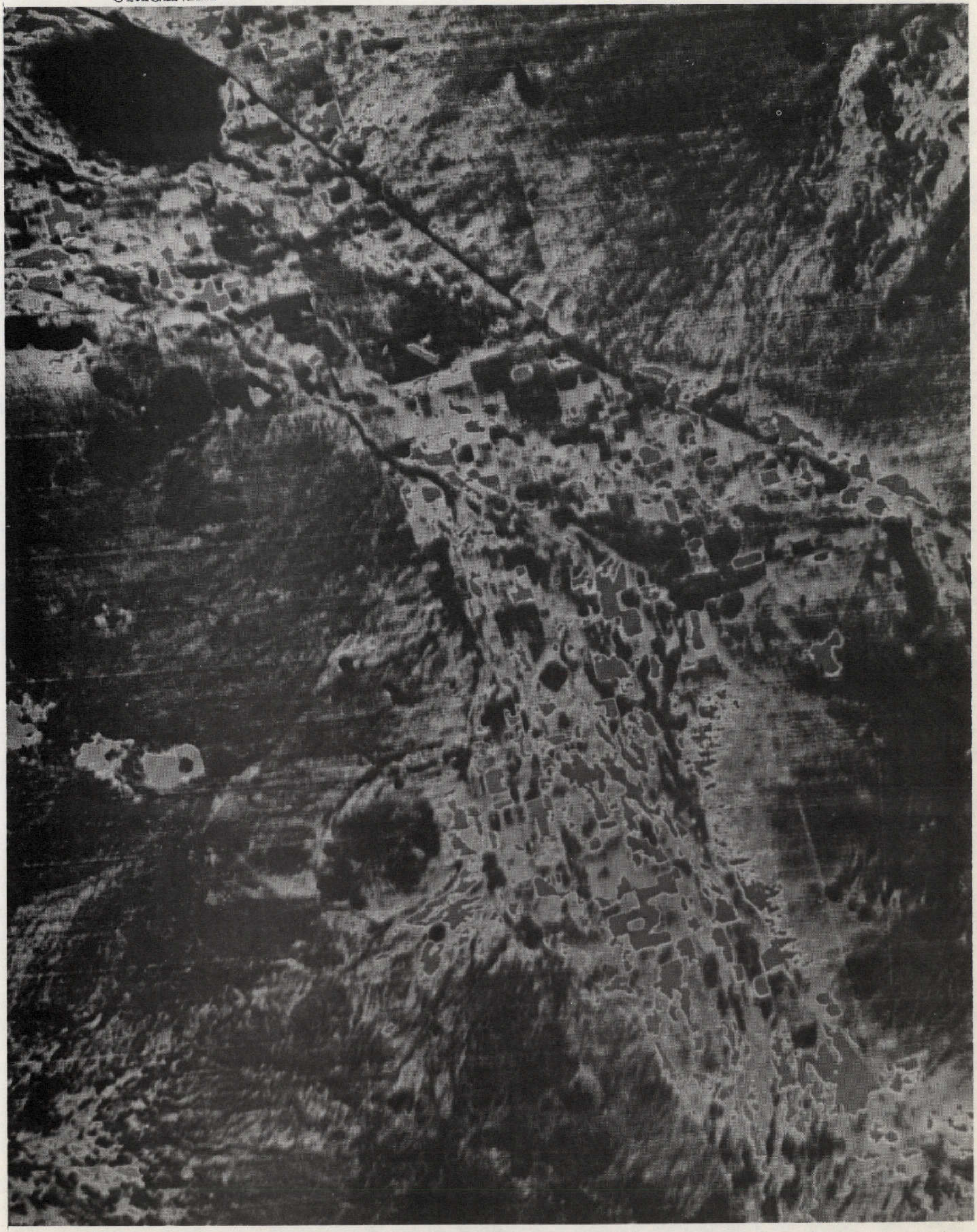


Figure 10: Method I, double exposure of A and B

Figure 11: Method I, Sandwich of A and B

Figure 14: Method II Final Product

Figure 13: Method II, Intermediate B

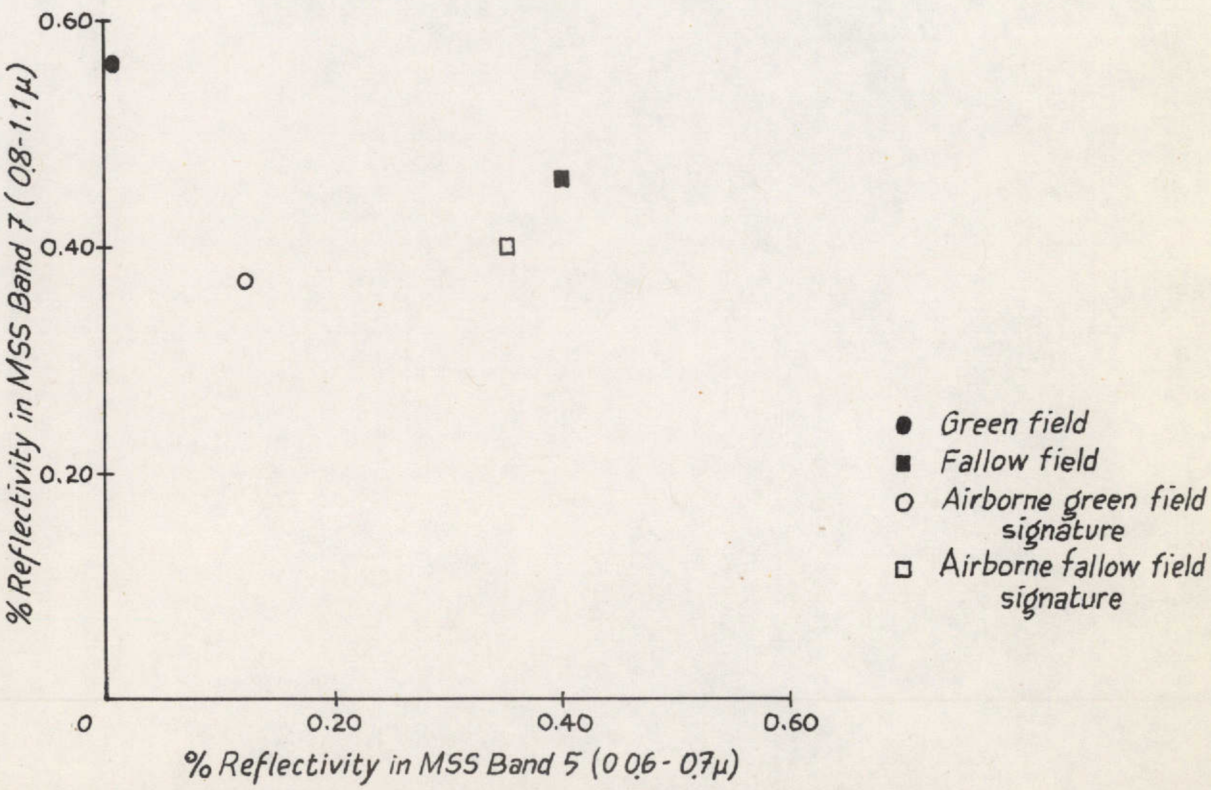



Figure 20. Reflectivities of Fallow and Planted Fields compared to overall airborne scene reflectivities.

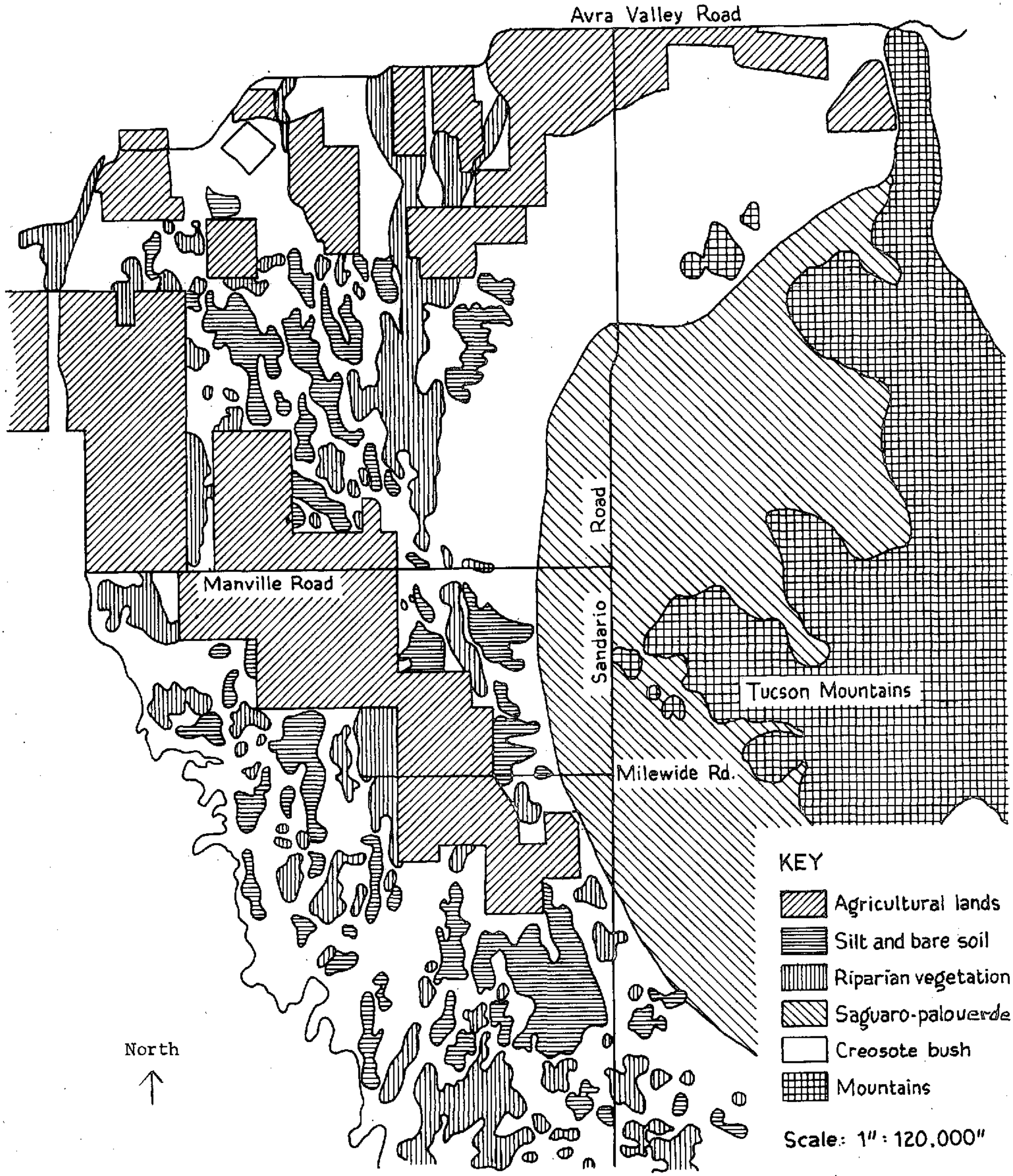



Figure 15. Vegetation Map of a Portion of the Avra Valley.

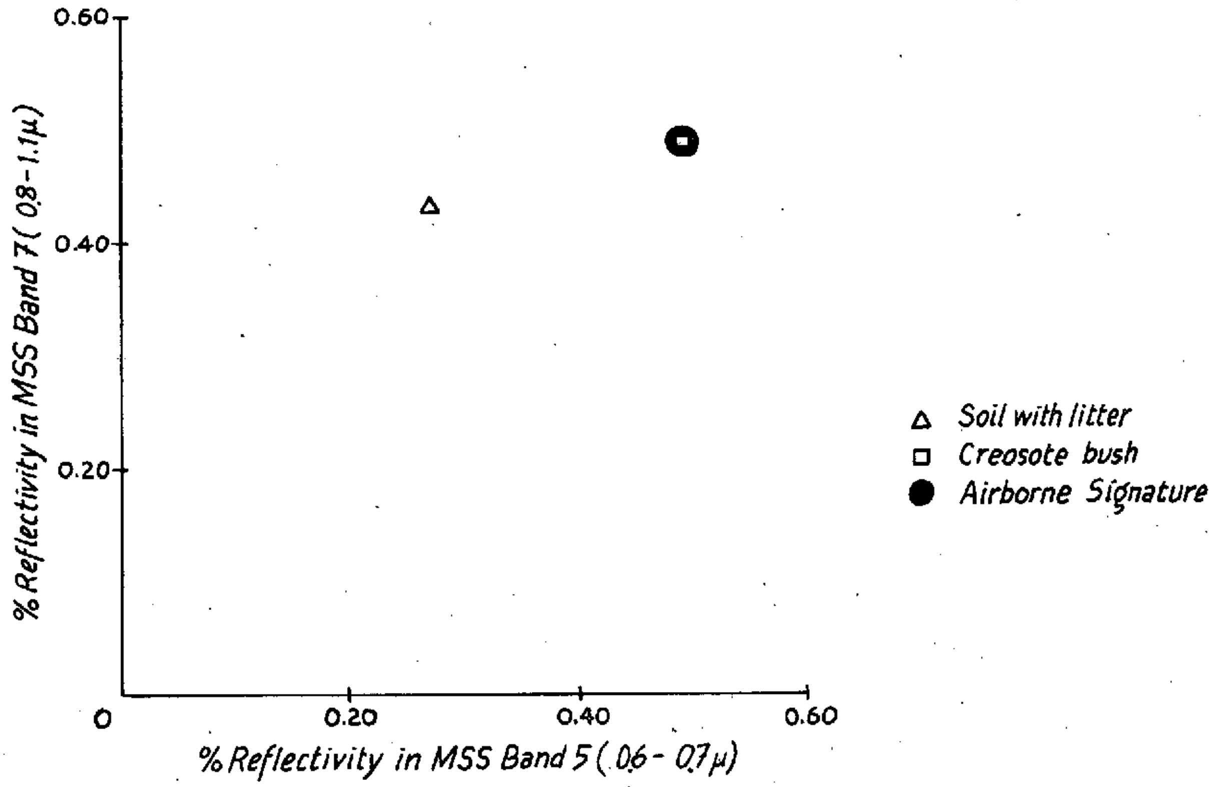



Figure 16. Reflectivities of *Larrea* (Creosote bush) site scene components compared to overall airborne scene reflectivity.

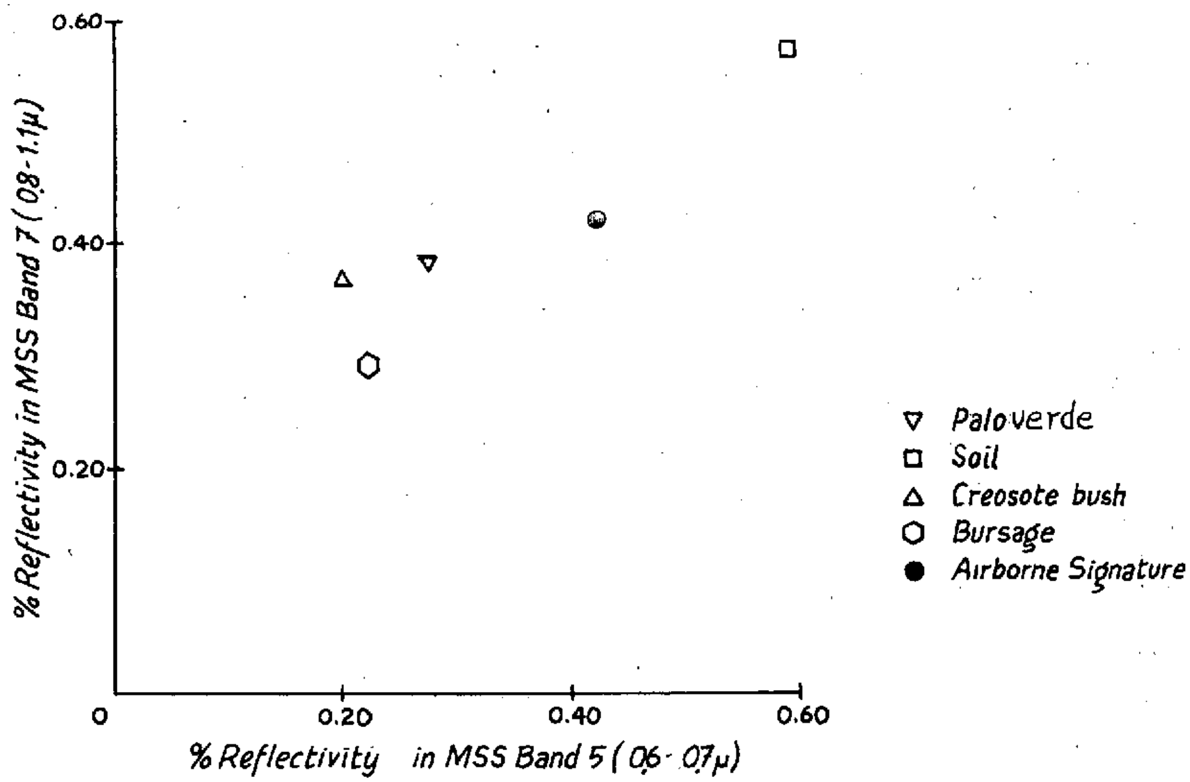



Figure 17. Reflectivities of Paloverde-Saguaro-Granite site scene components compared to overall airborne scene reflectivity.

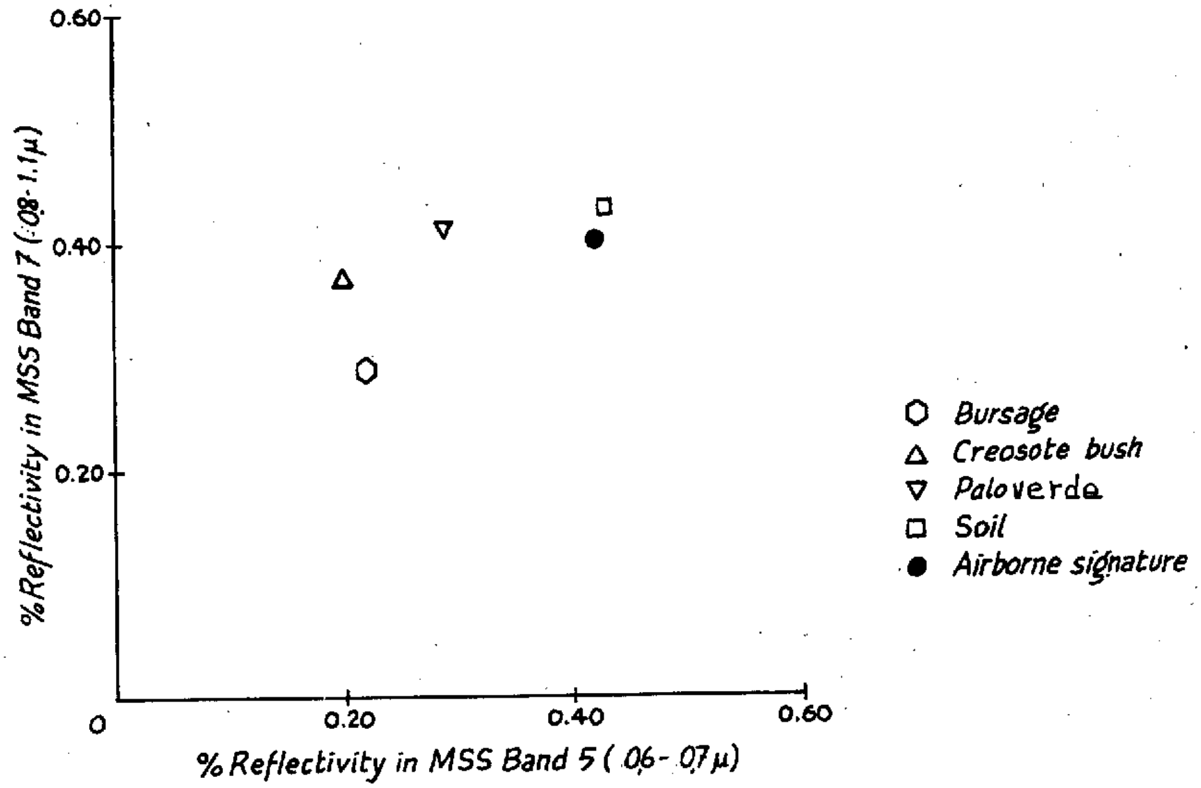



Figure 18. Reflectivities of Paloverde-Saguaro-Red Rock site scene components compared to overall airborne scene reflectivity.

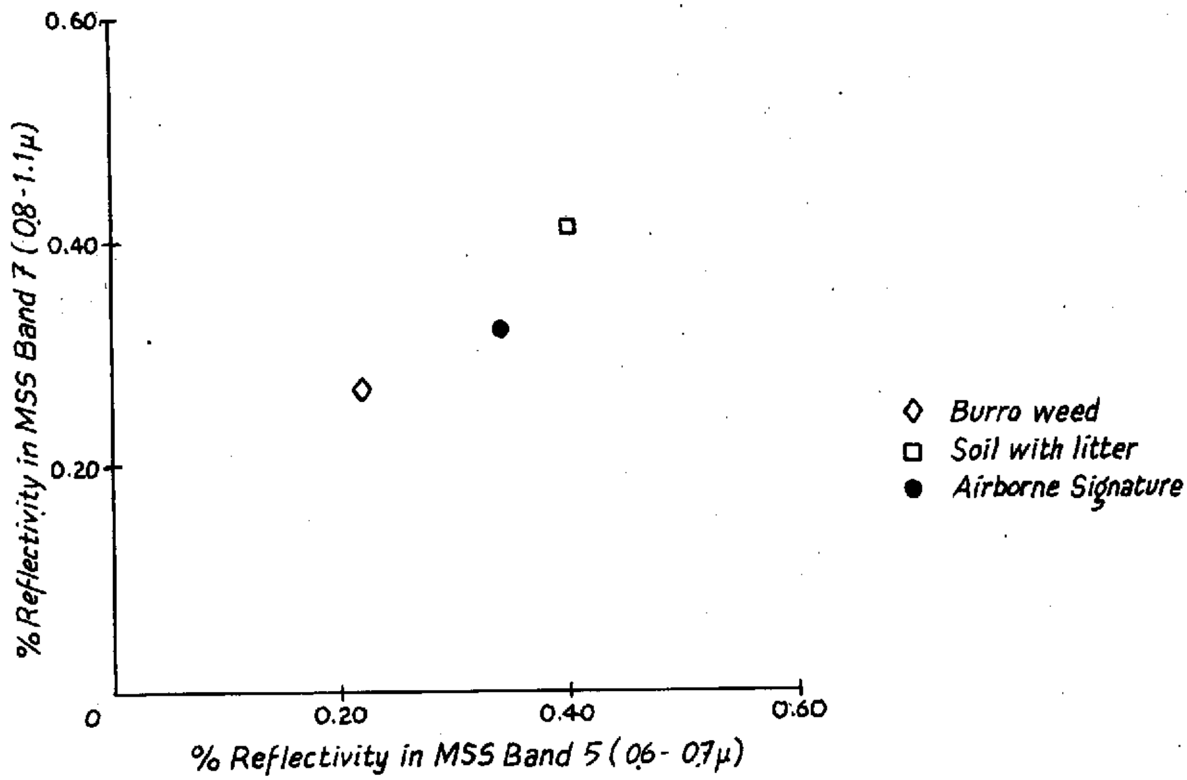



Figure 19. Reflectivities of Rothrock grama site scene components compared to overall airborne scene reflectivity.

## APPENDIX A

### A List of Reports and Papers

#### 1972 Bimonthly Progress Reports

| NTIS* No. | Title |
|---|---|
| E72-10159 | Haase, E.F., W.G. McGinnies and H.B. Musick. A study to explore the use of orbital remote sensing to determine native arid plant distribution. Type I Report #1. Office of Arid Lands Studies, University of Arizona. 2 pages. |
| E72-10314 | Haase, E.F., W.G. McGinnies and H.B. Musick. A study to explore the use of orbital remote sensing to determine native arid plant distribution. Type I Report #2. Office of Arid Lands Studies, University of Arizona. 2 pages. |

#### 1973 Bimonthly Progress Reports

| NTIS* No. | Title |
|---|---|
| E73-10520 | Haase, E.F., W.G. McGinnies and H.B. Musick. A study to explore the use of orbital remote sensing to determine native arid plant distribution. Type I Report #3. Office of Arid Lands Studies, University of Arizona. 4 pages. |
| E73-10659 | Haase, E.F., W.G. McGinnies and H.B. Musick. A study to explore the use of orbital remote sensing to determine native arid plant distribution. Type I Report #4. Office of Arid Lands Studies, University of Arizona. 4 pages. |
| | Conn, J.C., L.K. Lepley and W.G. McGinnies. A study to explore the use of orbital remote sensing to determine native arid plant distribution. Type I Report #5. Office of Arid Lands Studies, University of Arizona. |
| | Conn, J.C., L.K. Lepley, and W.G. McGinnies. A study to explore the use of orbital remote sensing to determine native arid plant distribution. Type I Report #6. Office of Arid Lands Studies, University of Arizona. |

#### 1973 Six-Month Reports

| NTIS* No. | Title |
|---|---|
| E73-10369 | Haase, E.F., W.G. McGinnies and H.B. Musick. A study to explore the use of orbital remote sensing to determine native arid plant distribution. Type II Report #1. Office of Arid Lands Studies, University of Arizona. 28 pages. |

Haase, E.F., W.G. McGinnies and H.B. Musick. A study to explore the use of orbital remote sensing to determine native arid plant distribution. Type II Report #2. Office of Arid Lands Studies, University of Arizona.

*Available through the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22151.

## Papers Presented

Haase, E.F., and H.B. Musick, 1973. The use of ERTS-1 Multispectral Imagery to Determine Native Desert Plant Distributions. Paper presented at 17th Annual Meeting of the Arizona Academy of Science, University of Arizona.

Haase, E.F., L.K. Lepley, W.G. McGinnies, and H.B. Musick, 1973. ERTS-1 Imagery and Native Plant Distributions, Paper presented at 4th Annual Meeting of ARETS Symposium, University of Arizona.